Great Lakes Fishery Laboratory

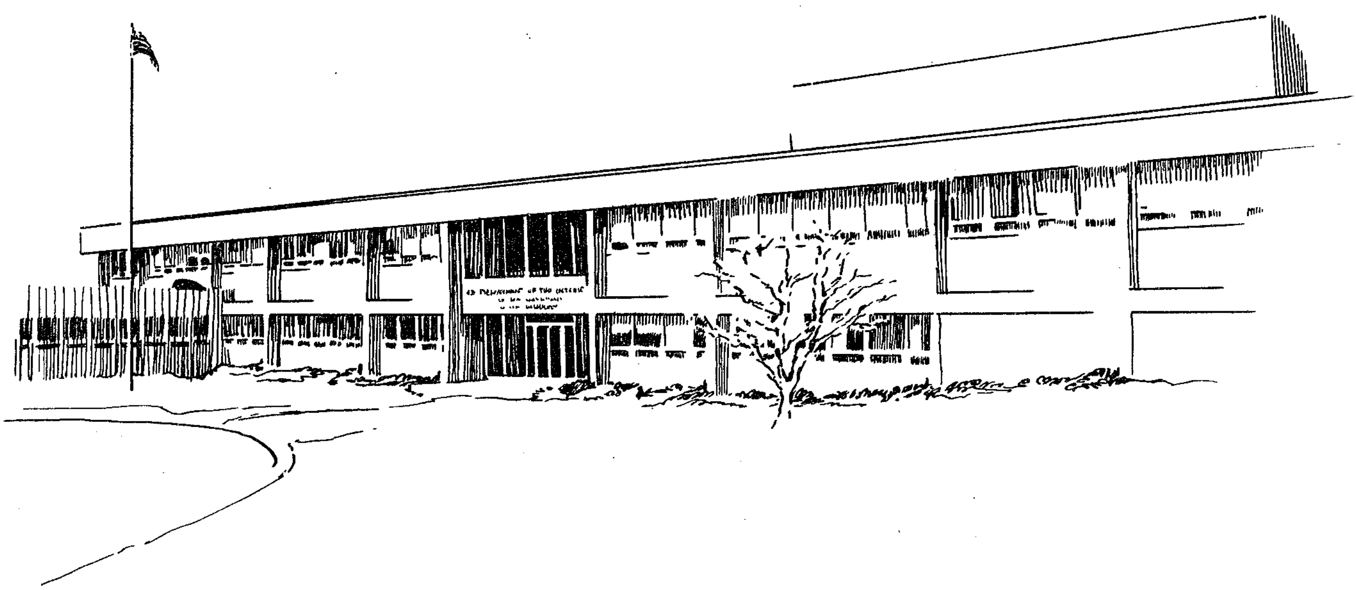
U.S. Fish and Wildlife Service
Ann Arbor, Michigan

ADMINISTRATIVE REPORT No. 80-4

COMPOSITION, DISTRIBUTION, AND DENSITY OF BENTHOS
IN THE LOWER ST. CLAIR RIVER, 1976-1977

Jarl K. Hiltunen

January 1980



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Prepared for the U.S. Army Corps of Engineers, Great Lakes and St. Lawrence Seaway, Navigation Season Extension Demonstration program, August 1978.

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U.S. Fish and Wildlife Service

1451 Green Road

Ann Arbor, Michigan 48105

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Summary of THE COMPOSITION, DISTRIBUTION, AND DENSITY OF MACROZOOBENTHOS IN THE LOWER ST. CLAIR RIVER, 1976-1977

1. As part of the Extended Winter Navigation Season Demonstration Program, the U.S. Army Corps of Engineers developed a conceptual plan to facilitate the movement of commercial vessels in the St. Clair River, and, by widening and deepening the mouth of the river's North Channel, to improve ice-floe movement.

2. From October 1976 to October 1977, the Great Lakes Fishery Laboratory conducted a Corps-funded study to provide baseline data on the macrozoobenthos of the lower St. Clair River to permit evaluation of potential effects of the proposed ice-floe diversion strategy on those aquatic invertebrates.

3. Analysis of 456 bottom samples were collected with a ponar grab at 38 stations in the St. Clair River from the village of St. Clair, Michigan, downstream to Lake St. Clair revealed a diverse and abundant macrozoobenthos fauna, except at the few stations where the substrate contained oil wastes. The Oligochaeta and immature insects were the most abundant invertebrates observed.

4. No estimates are available to indicate the probability of occurrence and severity of ice jams, dewatering, and bottom scour in the river's North Channel resulting from implementation of the Corp's ice-management strategy. Consequently we are unable to provide a quantitative estimate of the effects of these altered ice-movement patterns on the benthic invertebrate community.

5. Dredging proposed at the mouth of the river's North Channel would destroy or displace macrozoobenthos populations whose total densities range from about 4,000 to 45,000 organisms per square meter. Recolonization would be prevented if only hard substrate remained after dredging.

6. Macrozoobenthos constitute a major source of food for fish and waterfowl in the lower St. Clair River. Hence their extensive loss (without replacement) from that important waterbody, as a result of dredging, ice scour, dewatering, or other activities related to the enhancement of winter navigation, can be expected to have detrimental effects on the fishes and waterfowl that inhabit it.

Composition, Distribution, and Density of Macrozoobenthos in the Lower St. Clair River, 1976-1977

Introduction

In 1970, the Great Lakes-St. Lawrence Seaway Navigation Extension Demonstration Program was authorized by Congress (P.L. 91611, amended in 1974 by P.L. 93251) to test the practicability of extending commercial shipping through the winter season. Within the program are a number of strategies designed by the U.S. Army Corps of Engineers to expedite the passage of vessels through ice. One of these strategies calls for installing structures in the lower St. Clair River to reduce the amount of brash ice entering the river's South Channel, the channel used for navigation in winter (U.S. Army Corps of Engineers 1974). According to this strategy, an ice-floe diversion structure would be installed in the river's main channel, at the upstream end of Russell Island, and second and third ones would be constructed across the mouth of the river's Middle Channel and Chenal A Bout Rond (Fig. 1). Ice from the river's main channel would be diverted into Anchor Bay, Lake St. Clair, via the North Channel. This strategy also involves deepening and widening the mouth of the North Channel to accommodate the additional ice loading.

Concern for the possible adverse environmental effects of the Corps' proposed ice-management strategy for the lower St. Clair River prompted the Environmental Evaluation Work Group (EEWG) of the Winter Navigation Board to request that the Corps fund a study of the macrozoobenthos of the lower river. At the request of the U.S. Fish and Wildlife Service's East Lansing Field Office/Office of Ecological Services, which has representation in the EEWG, the Great Lakes Fishery Laboratory undertook a Corps-funded study of the macrozoobenthos in the lower St. Clair River. The study's primary objective was to establish an environmental baseline for future evaluation of the effects of the Corp's proposed ice-management strategy (Appendix 1).

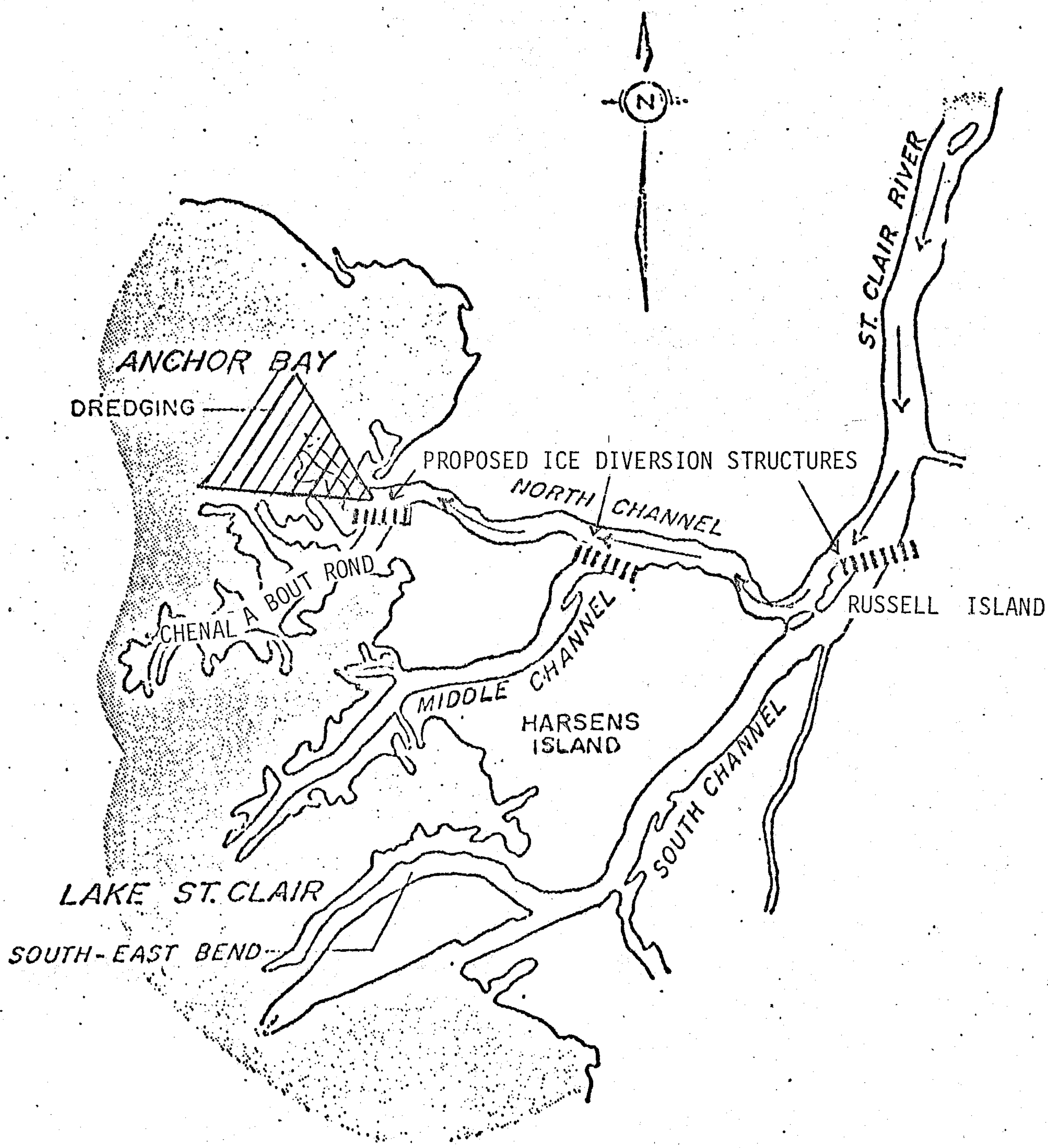

Figure 1. Location of proposed ice-floe diversion structures and dredging site in the St. Clair River. Map after U.S. Corps of Engineers (1974).

Methods and Materials

We sampled for macrozoobenthos at 38 stations in the lower St. Clair River, from the village of St. Clair, Michigan, downstream to Lake St. Clair (Fig. 2, Appendix 2). The stations were arranged mostly in pairs, one station on either side of the channel. Station water depths were 0.9-4.6 m, except at stations 24 and 36 where the depths were 7.3 and 10.9 m, respectively. We sampled in October 1976 and March and May 1977 to show seasonal changes, and in October 1977 to provide an estimate of year-to-year variation. Three replicate samples were taken with a 22-cm-square ponar grab at each visit to a station. On station, each grab sample was washed through a U.S. Standard No. 30 wire-mesh sieve; the residue containing the organisms was fixed in 10% formalin. In the laboratory, the macrozoobenthos was extracted from the residue with the aid of a dissecting microscope and its components identified to the lowest taxonomic rank feasible. The resultant data were tabulated by computer (Appendix 3).

A total count of all organisms in each grab sample was attempted (except for the bryozoans, which live as a colonial mass and could not be counted individually), but when the numbers of the epiphytic forms in any sample were exceedingly large, enumeration was stopped after 100 individuals had been recorded (e.g., see Appendix 3 for <u>Hydra</u> at station 5, October 1976).

Because of the high numbers of Oligochaeta per grab, classification of these animals beyond the subclass rank was not generally feasible. To attain an indication of species diversity within the group, we identified to family and species the specimens in one grab sample, taken at station 4 on October 23, 1976. Also recorded during each visit to a station were water transparency (Secchi disk), surface temperature, and substrate type (Appendix 4).

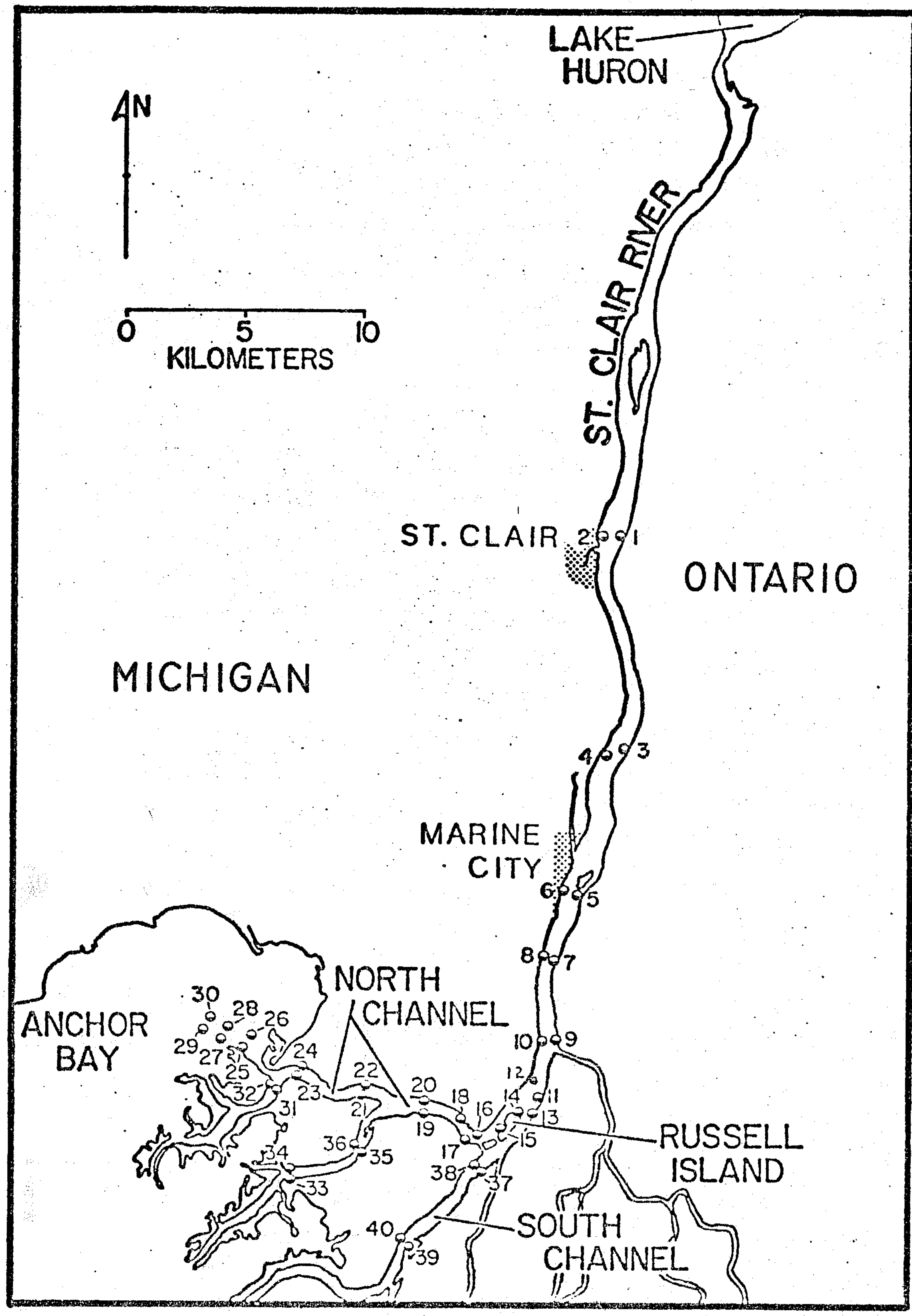

Figure 2. Location of macrozoobenthos-sampling stations in the lower St.Clair River, 1976-1977. (Attempts to sample at stations 2 and 12 were unsuccessfull due to hard bottom.)

Findings

The St. Clair River system supports a diverse and abundant macrozoobenthos (Table 1, Appendix 3). The number of taxa found in the present study was significantly greater than that reported for each of the five Great Lakes, except Lake Erie (Great Lakes Basin Commission 1976), indicating that the secondary productivity of the St. Clair River is high. Organisms in 14 taxonomic groups composed the bulk of the benthic fauna (Table 1). Excluded from Table 1 are forms whose proportion in the total fauna was low (<1%) and those (Rhabdocoela, Tricladida, and *Hydra*) that were numerous but are principally epiphytic and whose density (no./m^2) cannot therefore be expressed accurately relative to the area of bottom sampled.

The quality of the benthic environment was high in most portions of the river sampled. At a number of stations where an oil film was detectable on the substrate surface (Appendix 4) the total fauna was least abundant (Appendix 3). Toxic fractions in the oil may have accounted for the lower numbers of organisms (Bengtsson and Berggren 1972; Emery 1972).

The Oligochaeta were the most abundant macrozoobenthos (approximately 50-56% by number) found in the samples (Table 1). The apparent decline in oligochaete densities from October 1976 to October 1977 may be a reflection of natural cyclic fluctuation in population density. A diagnostic examination of the oligochaetes in one grab sample taken at station 4 revealed at least 16 species (Table 2). The large number of species found in that sample is similar to that found in benthos collections from Lake St. Clair (Hiltunen 1971).

Dipteran larvae were the second most abundant macrozoobenthos present. They made up about 19-26% of the total fauna. By number, the Chironomidae composed 95% of the dipterans; the remaining 5% included Empididae, Ceratopogonidae, Culicidae (*Chaoborus*), Psychodidae, and Dolichopodidae.

Table 1. Percentage composition and mean density (number of individuals per square meter) of 14 major taxa represented in the macrobenthos in the St. Clair River, 1976-77.

Taxa	1976 October Composition %	1976 October Density No./m^2	1977 March Composition %	1977 March Density No./m^2	1977 May Composition %	1977 May Density No./m^2	1977 October Composition %	1977 October Density No./m^2
NEMERTINEA	1.0	223	0.3	37	0.1	19	1.3	128
NEMATODA	1.7	371	3.0	397	3.4	450	1.7	173
HIRUNDINEA	0.1	17	0.1	10	0.2	28	0.1	14
OLIGOCHAETA	51.5	11029	62.6	8380	52.7	6979	49.2	4986
AMPHIPODA	8.1	1746	2.6	352	5.1	674	11.2	1136
ISOPODA	0.8	180	0.1	16	0.4	50	0.3	33
DIPTERA	22.9	4897	19.4	2596	26.3	3481	20.5	2079
EPHEMEROPTERA	0.5	107	0.7	97	0.8	100	1.9	189
COLEOPTERA	0.1	17	0.1	10	0.1	15	0.1	7
LEPIDOPTERA	0.1	16	0.2	20	0.7	91	0.2	19
TRICHOPTERA	0.5	106	0.4	50	0.2	33	0.7	66
HYDRACARINA	0.3	54	0.3	41	0.3	38	0.1	6
GASTROPODA	8.6	1851	6.0	802	6.7	883	8.6	870
PELECYPODA	3.8	807	4.4	587	3.0	402	4.2	422
TOTALS	100.0	21420	100.0	13396	100.0	13242	100.0	10129

Excluded from the table: Hydra, Rhabdocoela, Tricladida, Bryozoa, Polychaeta, Cladocera, Ostracoda, Decapoda, Hemiptera, Odonata, and Plecoptera.

Table 2. Species of Oligochaeta found in one grab sample taken at station 4, on October 23, 1976, St. Clair River.

Taxon		No./grab	No./m^2
Enchytraeidae		2	41
Naididae			
Chaetogaster diaphanus		6	124
Ophidonais serpentina		2	41
Specaria josinae		2	41
Stylaria lacustris		1	21
Wapsa mobilis		89	1,839
Tubificidae			
Aulodrilus limnobius		1	21
A. pigueti		46	950
A. pluriseta		7	145
Ilyodrilus templetoni		2	41
Limnodrilus hoffmeisteri		1	21
L. udekemianus		18	372
Peloscolex ferox		160	3,306
Peloscolex multisetosus		62	1,281
Potamothrix moldaviensis		18	372
P. vejdovskyi		1	41
Unidentifiable immature			
with capilliform chaetae		161	3,326
without capilliform chaetae		524	10,826
	Total	1,103	22,809

Amphipoda were among the less abundant forms and were represented by Gammarus sp., Hyalella azteca, Crangonyx sp., and Pontoporeia hoyi. Of these, three are permanent residents of the St. Clair River; the fourth, P. hoyi, populates deep waters of the Great Lakes, the few we observed being probable transients from Lake Huron.

Among the mollusks collected, the snails (Gastropoda) were most abundant. Common genera included Amnicola, Goniobasis, Physa, and Valvata. Encotec (1974) also reported Goniobasis as common in the river. The pelecypod populations were composed primarily of Pisidium; Sphaerium and unionid clams were infrequent.

Two genera, Asellus and Lirceus, composed the Isopoda. Asellus is known from various parts of the Great Lakes drainage, but Lirceus has been previously reported only from the St. Marys River (Veal 1968).

The Trichoptera and Ephemeroptera together composed only about 1-2% of the total number of major macrozoobenthic groups. Trichopterans were not as numerous as mayflies but were represented by a greater number of genera. The ephemeropterans were largely (90-98%) Hexagenia. Although the density of mayflies and caddisflies was low, these organisms are, nevertheless, a significant part of the total fauna because the biomass of their populations is greater than that of most other insect groups.

In general, numbers of Hexagenia declined from October 1976 to May 1977. Following recruitment in mid-summer, the population of mayfly nymphs increased and was again highest in October 1977. Nymphal densities in October 1977 were much larger than in 1976, indicating greater recruitment in 1977. The seasonal trend in population size of all Trichoptera combined was similar to that in Hexagenia, but fewer trichopterans were found in 1977 than in 1976.

Depth also appears to be a factor that greatly influences the distribution, abundance, and composition of benthos. The greatest depth sampled (7.3 meters, at station 36) yielded the fewest numbers and kinds of organisms.

Discussion

Although ice-management strategies, which include the installation of ice-floe diversion structures, have been proposed by the U.S. Army Corps of Engineers (1974), detailed predictions of the effects of the implementation of these strategies on ice movement have not been made available by the Corps. Without these ice-movement predictions, particularly those describing the probable location, frequency of occurrence, and duration of ice dams, and the scouring of benthic habitat by ice, we are unable to offer a quantitative estimates of the impact on the macrozoobenthos of the St. Clair River of proposed ice-management tactics.

However, if all drifting ice in the main channel is diverted into the North Channel, as is indicated by one of the Corps' strategies (Fig. 1), the incidence of ice jams would likely increase in that branch of the river. Jams extensive enough to block or impede flow in the channel could cause dewatering downstream in the littoral zone thereby exposing bottom fauna to dessication and to air temperatures below the freezing point of water.

If the proposed strategies for modifying the movement of ice in the St. Clair River as outlined in Figure 1 are implemented, the associated dredging at the mouth of the North Channel will displace or destroy the large standing crop of macrozoobenthos in that area (approximately 4,000-45,000/m^2, cf. stations 25-30, Appendix 2). Recolonization by that fauna will be slow, or may not occur in significant degree because the deepened bottom will be hard and inhospitable to most forms.

Macrozoobenthos constitutes a very important source of food for fish and waterfowl in the St. Clair River. Price (1963) showed that rainbow smelt, alewives, gizzard shad, spottail shiners, trout-perch, yellow perch, channel catfish, white bass, and walleyes feed heavily at different life stages on oligochaetes, leeches, cladocera, ostracods, amphipods, ephemeropterans, trichopterans, dipterans, gastropods, and pelecypods in Lake Erie. Yellow perch, for example, have been reported to feed on Physa (Hiltunen 1971), a snail that was notably abundant at the mouth of the North Channel where dredging has been contemplated. Although little other published work exists on the food habits of St. Clair River fishes, the aforementioned fishes and the invertebrates that they feed upon are all abundant in the St. Clair River. Dawson (1975) has revealed that many of the organisms encountered in the present study are also important sources of food for waterfowl in Anchor Bay, Lake St. Clair. Consequently, the extensive loss (without replacement) of macrozoobenthos in the lower St. Clair River, through dredging, ice scour, dewatering, or other activities related to the enhancement of winter navigation, can be expected to have detrimental effects on the fishes and waterfowl that permanently reside there or inhabit it at different seasons and/or life stages.

Summary

The St. Clair-Detroit River system is an important recreational resource for large numbers of people in the vicinity of metropolitan Detroit. These waters support valuable fishery resources that are being heavily used by U.S. and Canadian anglers. These resources may be damaged by physical alteration of the benthic environment if proposed engineering strategies to divert ice-floes from the river's main channel into the river's North Channel in the St. Clair delta are implemented. Increased amounts of floating ice in the North Channel would increase the incidence of jamming thereby causing bottom scour or other undesirable alteration of the (bottom) habitat, and, in turn, impairment of the benthos it supports. A study of the standing crop of macrozoobenthos in the lower St. Clair River was conducted by the Great Lakes Fishery Laboratory in 1976-77 to provide a baseline against which the impact of the Corps' ice-management strategies can be adequately assessed. The benthic invertebrate fauna included a number of organisms which have been shown to be important in the diet of fishes. Among these invertebrates were numbers of immature forms of mayflies and caddisflies, all of which are sensitive to disturbance or alteration of their habitat.

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APPENDIX 1

GREAT LAKES AREA OFFICE
Room 301 Manly Miles Building
1405 S. Harrison Road
East Lansing, Michigan 48823

April 21, 1976

Dr. Joseph H. Kutkuhn, Director
Fish and Wildlife Service
Great Lakes Fishery Laboratory
1451 Green Road
Ann Arbor, Michigan

Dear Dr. Kutkuhn:

This letter regards the Winter Navigation Demonstration Program on the Great Lakes and your proposed biological study of the St. Clair system. First, let me take this opportunity to inform you that my staff and I are pleased in regard to your upcoming study of this system. The baseline data anticipated to be collected will be valuable in our task of preserving what remains of the complex St. Clair ecosystem.

Pending the extension of the Winter Navigation Season Extension Demonstration Program for an additional two years, $50,000 should be available to the Fish and Wildlife Service through the Environmental Evaluation Work Group for FY-77. The purpose of the funds is for environmental baseline studies to aid in future evaluation of structural improvements on the St. Clair system. Upon being informed of your proposed study on this system, Mr. Stoll approached Messrs. Edsall and Hiltunen of your staff to inquire whether GLFL would be interested in the $50,000 as additional funding toward your investigation of the St. Clair system. The response was favorable. It was mentioned that the funds could be utilized toward the benthic portion of the total study which we understand is scheduled to begin this fall. As background information of the Corps of Engineers' proposals to extend the navigation season through the St. Clair-Detroit River system, Mr. Edsall was supplied with a copy of the "System Study to Extend Navigation Season on St. Clair-Detroit River System (three volumes).

We would like at this time a letter stating your intent regarding the utilization of the $50,000 of Winter Navigation Demonstration funds. The only firm requirements that we have are that some of the sample stations be in the St. Clair River proper (above Marine City, Michigan), some form of progress report (preferably written) be supplied on a quarterly basis, and that a date for submission of a report of findings be given. As a matter of course my staff will be available to you to aid in scoping the study. When you have developed a scope of work for the study or for the benthic portion at least, we would appreciate a copy. We would then use the scope of work to inform the Corps of Engineers (lead agency for the Winter Navigation Season Extension Demonstrtion Program) as to how the money is to be spent.

If you have any questions please feel free to contact Mr. Bob Seppala of my staff who has replaced Mr. Mike Stoll. Again, we look forward to the St. Clair Study results since they will be invaluable to the environmental evaluation of the program.

Sincerely,

Clyde R. Odin

Appendix 2. Coordinates for location of macrozoobenthos sampling stations in the St. Clair River, 1976-77. (Attempts to sample at stations 2 and 12 were unsuccessful due to hard bottom.)

Station		Location N latitude ° ' "	Location W longitude ° ' "
1		42 49 16	82 28 25
2	(No data)	42 49 16	82 29 08
3		42 44 51	82 28 15
4		42 44 40	82 29 00
5		42 41 44	82 29 42
6		42 41 48	82 30 10
7		42 40 09	82 30 20
8		42 40 14	82 30 45
9		42 38 25	82 30 20
10		42 38 28	82 30 50
11		42 37 27	82 30 40
12	(No data)	42 37 15	82 31 22
13		42 37 02	82 30 51
14		42 37 06	82 31 20
15		42 36 33	82 32 00
16		42 36 27	82 32 35
17		42 36 21	82 32 52
18		42 36 48	82 33 10
19		42 36 57	82 34 15
20		42 37 09	82 34 14
21		42 37 18	82 36 20
22		42 37 25	82 36 20
23		42 37 42	82 38 10
24		42 37 55	82 38 00
25		42 38 32	82 40 20
26		42 38 42	82 40 20
27		42 38 36	82 40 50

Appendix 2. Continued.

Station	Location		
	N latitude		W longitude
	° ' "		° ' "
28	42 38 42		82 40 50
29	42 38 36		82 41 25
30	42 38 42		82 41 25
31	42 37 22		82 38 45
32	42 37 28		82 38 50
33	42 35 30		82 38 15
34	42 35 38		82 38 15
35	42 36 08		82 36 00
36	42 36 12		82 36 10
37	42 35 33		82 32 37
38	42 35 38		82 32 55
39	42 34 00		82 34 33
40	42 34 15		82 34 38

Appendix 3. Number per grab and mean estimated density of macrozoobenthos collected at 38 stations in the St. Clair River, 1976-77. Estimates of mean estimated densities were achieved by multiplying the mean count of organisms found in the three grabs by 20.66. (Attempts to sample at stations 2 and 12 were unsuccessful due to hard bottom.)

Only an example page of Appendix 3 is reproduced as part of this administrative report. The data are available on request from the Great Lakes Fishery Laboratory.

MACROBENTHOS OF THE ST. CLAIR RIVER STATION 01

DATE	DEPTH(M.)	TAXON	--GRAB COUNTS--			MEAN NO./M2
10/23/76	1.2	CNIDARIA				
		HYDRA	114	245	543	6212
		ALL CNIDARIA				6212
		TRICLADIDA	7	0	5	83
		NEMERTINEA	0	38	13	351
		NEMATODA	9	63	2	510
		BRYOZOA	+	0	0	
		HIRUDINEA				
		ERPOBDELLIDAE	1	0	0	7
		OLIGOCHAETA				
		CHAETOGASTER	21	238	57	
		STYLARIA LACUSTRIS	2	0	0	
		OTHER	759	936	84	
		ALL OLIGOCHAETA				14441
		AMPHIPODA				
		GAMMARUS	0	1	2	21
		ALL AMPHIPODA				21
		DIPTERA				
		CHIRONOMIDAE	14	63	50	875
		EMPIDIDAE	1	0	0	
		ALL DIPTERA				881
		LEPIDOPTERA	1	2	0	21
		ACARINA	1	19	13	227
		GASTROPODA				
		AMNICOLA	9	7	2	
		GONIOBASIS LIVESCENS	0	12	25	
		GYRAULUS	35	26	26	
		LYMNAEA	3	47	0	
		PHYSA	77	27	57	
		VALVATA SINCERA	93	53	45	
		VALVATA TRICARINATA	207	38	40	
		ALL GASTROPODA				5709
		PELECYPODA				
		PISIDIUM	80	12	1	640
		ALL PELECYPODA				640

Example page of Appendix 3.

Appendix 4. Hydrographic data taken at macrobenthos sampling stations in the St. Clair River, 1976-77. (I, II, III, and IV represent the time periods, October 23-November 4, 1976, March 23-30, 1977, May 12-14, 1977, and October 25-28, 1977, respectively.)

Station	Depth (m)				Secchi disk (m)				Temperature (°C)				Substrate type[1/]			
	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
1	1.2	0.9	0.9	1.2	3.4	0.8	O/B[2/]	O/B	10.0	2.5	9.5	12.0	M,S	M,S,O	S,G,	M,S
3	2.4	2.4	2.4	2.4	2.1	0.9	1.5	1.3	10.5	4.0	10.0	12.5	M,C	C	C	G,C
4	4.0	4.6	4.6	4.0	1.5	0.9	2.0	1.7	10.3	4.0	10.0	12.5	M,S	M,S	Si,S	M,S
5	2.1	2.1	2.1	2.1	1.4	0.9	1.4	O/B	10.3	4.0	9.0	12.0	M,S	M,S	Si,S	M,S
6	3.7	3.4	3.4	4.0	1.8	0.8	1.5	1.7	10.5	4.0	10.0	12.5	Si,G,C	G,C	G,C	G,C
7	3.0	3.0	3.0	3.0	1.8	0.9	1.2	1.4	10.5	2.5	10.5	12.0	Si	Si	G,C	M,S
8	3.4	2.7	2.7	3.4	1.5	0.9	1.7	1.6	10.0	3.0	9.5	12.5	Si,G,C	Si,S	Si,S	M,G
9	3.0	2.7	2.7	3.0	1.5	0.9	1.5	1.4	10.5	3.0	9.5	12.0	M,S,O	M,S,O	Si,S	M,S,O
10	3.0	3.0	3.0	3.0	1.8	0.8	1.8	2.0	10.0	3.0	9.5	12.5	Si,M,S,C	M,S,	Si,M	M
11	1.2	3.0	3.0	1.2	O/B	0.6	1.7	1.3	8.3	4.0	9.5	11.5	Si,S	Si,S,O	Si,S	Si,S
13	1.5	1.5	1.5	1.5	1.2	0.9	O/B	1.6	8.1	5.0	9.5	11.8	M,Si	Si,M	M,G	S,G
14	2.4	2.4	2.4	2.4	O/B	1.2	O/B	1.5	10.0	3.5	9.0	11.8	S,G	Si,S	Si,S	Si,S
15	3.7	3.7	3.7	3.7	1.7	1.2	1.4	1.3	8.1	5.0	9.5	12.0	M	Si,M	Si,M	M
16	1.8	1.8	1.8	1.8	1.7	0.8	O/B	1.3	8.1	4.5	9.5	12.0	M,S	M	M	M
17	1.8	1.8	1.8	1.8	1.7	1.2	O/B	1.7	7.2	4.5	9.0	11.8	Si	Si,S	Si,M	M,G
18	2.1	2.1	2.1	2.1	1.4	0.9	1.5	1.3	7.8	5.0	9.5	12.0	Si,M	Si,M	Si,S	M
19	2.4	2.4	2.4	2.4	1.4	1.2	1.1	1.0	7.2	4.0	9.0	12.0	Si,M	M	Si,M	M
20	3.7	3.0	3.0	3.7	1.4	0.9	1.2	1.3	8.1	4.0	9.0	12.1	M,C	G,C	S,C	M,G
21	4.3	4.3	4.3	4.3	1.5	1.2	1.1	1.6	8.3	4.7	8.5	12.0	Si,S	Si,S,O	M	Si,S
22	3.7	3.7	3.7	3.7	1.1	1.1	1.1	1.3	8.3	5.0	-	12.0	Si,S	Si,S	M,S	Si,M
23	2.4	2.4	2.4	2.4	1.1	1.2	1.1	1.6	8.1	5.5	9.0	11.9	Si,M	Si,M	Si,M,O	M,S

Appendix 4. (continued)

Station	Depth (m) I	II	III	IV	Secchi disk (m) I	II	III	IV	Temperature (°C) I	II	III	IV	Substrate type[1] I	II	III	IV
24	1.2	7.3	7.3	1.2	O/B[2]	0.9	1.1	1.5	8.3	5.0	9.0	11.0	Si,S	Si,S	Si,S	Si,M
25	2.1	2.1	1.5	2.1	1.2	0.9	O/B	1.3	9.2	5.6	8.5	12.0	Si,M	M	Si,M	Si,M
26	2.4	2.1	2.1	2.4	1.1	1.1	1.5	1.5	8.3	4.5	8.5	12.0	Si,M	M,S	Si,M	Si,M
27	1.2	1.2	1.5	1.2	O/B	0.9	O/B	O/B	8.8	4.0	8.5	-	Si,S	M,S	M,S	Si,M
28	1.8	1.5	1.5	1.8	1.2	1.1	O/B	1.4	8.8	4.6	8.5	12.0	Si,M	M,S	S,C	Si,C
29	3.0	3.0	3.0	3.0	1.2	0.9	1.4	1.8	8.8	4.0	8.5	12.0	M	M,S	M	Si,M
30	3.7	3.7	3.7	3.0	1.2	0.9	1.5	1.3	8.5	4.0	8.5	12.0	M,S	M,S	M	Si,M
31	2.1	2.1	2.1	2.1	0.9	0.8	1.1	1.5	6.9	5.0	9.0	11.8	M,C	Si,M	Si,C	M,S
32	3.0	3.0	3.0	3.0	-	1.2	1.1	1.7	-	5.5	9.0	11.5	M,S	G,C	Si,M	S,Peat
33	3.7	3.0	3.0	3.7	1.4	0.9	1.2	1.5	8.3	5.0	9.5	12.0	M,S	Si,S	Si,M	M,C
34	3.0	3.0	3.0	3.0	1.5	0.9	1.2	1.7	8.3	5.0	9.5	12.0	M,S	M,S	Si,M	M,C
35	4.6	4.6	4.6	4.6	-	0.9	1.1	1.7	9.0	2.5	9.0	12.0	M,S	Si,S	Si,S	M
36	9.1	9.1	9.1	9.1	-	0.9	1.1	2.2	10.5	2.5	9.0	12.0	C	G,C	Si,C	M,C
37	1.8	1.8	1.8	1.8	1.5	0.9	1.5	1.3	8.3	5.0	9.0	11.5	Si,S	M,S	M,S	M
38	1.8	1.8	1.8	1.8	1.5	1.2	O/B	1.3	7.8	4.0	9.0	11.5	Si,M	M,C	M,S	M
39	2.1	2.4	2.4	2.1	1.4	0.9	1.4	1.2	7.8	4.7	9.0	11.5	M	Si,M	M	M
40	1.8	1.8	1.8	1.8	1.5	1.2	O/B	1.3	7.8	4.0	8.5	11.5	Si,M	M,S	M,S	M

1/ C = clay; G = gravel; M = mud; S = sand, Si = silt; O = oil.

2/ O/B denotes that Secchi disk was visible resting on the bottom.